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INTRODUCTION

This report relates to the flood situation along the Clark Fork in the vicinity of Missoula, Montana. The Montana State Water Resources Board requested this report be prepared to aid in the solution of local flood problems and in the best utilization of land subject to overflow. The report is based upon information on rainfall, runoff, historical and current flood heights, and other technical data bearing upon the occurrence and size of floods in the Missoula area.

The report covers two significant phases of the Missoula flood problem. It first brings together a record of the largest known floods on the Clark Fork. Secondly, it treats of probable future floods: namely, Intermediate Regional Floods and Standard Project Floods. Intermediate Regional Floods are floods that have an average frequency of occurrence in the order of once in 100 years and are determined from an analysis of known floods on the Clark Fork and other streams which have similar physical characteristics and are in the same general geographical region. Standard Project Floods are of rare occurrence and, on most streams, are considerably larger than any floods that have occurred. However, they should be considered in planning for use of the flood plains.

In planning for the control of development in the flood plains of Clark Fork and in making decisions on the size of floods to consider for this purpose, appropriate consideration should be given to the recurrence of floods and to the possible larger future floods of the magnitude of the Intermediate Regional Floods and the Standard Project Floods.

The report contains maps, profiles, and cross sections which indicate the extent of flooding that has been experienced and that which might occur in the future in the vicinity of Missoula.

This should prove helpful in planning the best use of the flood plains. From the maps, profiles, and cross sections, the depth of probable flooding either by recurrence of the largest known floods or by occurrence of the Intermediate Regional or Standard Project Floods at any location may be learned. With this information, floor levels for buildings may be planned high enough to avoid flood damage or, if at lower elevations, with recognition of the chance and hazards of flooding that are being taken.

The report does not include plans for the solution of flood problems. Rather, the report is intended to provide the basis for further study and planning on the part of the Montana State Water Resources Board, the city of Missoula and Missoula County in arriving at solutions to minimize vulnerability to flood damages. This might involve local planning programs to guide developments by controlling the type of use made of the flood plain through zoning and subdivision regulations, the construction of flood protection works, or a combination of the two approaches.

The Seattle District of the Corps of Engineers will, upon request, provide technical assistance to Federal, State, and local agencies in the interpretation and use of the information contained herein and will provide other available flood data related thereto.

SUMMARY OF FLOOD SITUATION

The city of Missoula, Montana, is on both banks of the Clark Fork (see Plate 1). The Clark Fork flows in a northwesterly direction through Missoula. This report covers a reach of 10 river miles which includes 6.5 miles of urban type development.

The principal residential development of Missoula is on high ground, but there are commercial and some residential development on land along Clark Fork. Orchard Homes, an unincorporated suburban community directly downstream of Missoula on the left bank, lies partially within the flood plain. Portions of this community have been inundated by floods of the past, and a substantially greater area is within reach of the potentially larger floods of the future.

The U. S. Geological Survey has maintained a stream gaging station on Clark Fork 3 miles east of Missoula at river mile 361.6 since March 1929. Newspaper files and historical documents have been searched for information concerning past floods. From these investigations and from studies of possible future floods on Clark Fork, the local flood situation, both past and future, has been developed. The following paragraphs summarize the significant findings which are discussed in more detail in succeeding sections of this report.

* * *

THE GREATEST FLOOD on the Clark Fork at Missoula, during the past 100 years occurred in June 1908. Newspapers pointed out the disastrous proportions of the flood at Missoula, and leave no doubt that it was far greater than any flood known to the oldest residents at that time.

* * *

ANOTHER GREAT FLOOD, in June 1964, was the third highest flood on the Clark Fork. The second highest flood was recorded in 1899. The 1964 flood was about 3 to 5 feet lower than the June 1908 flood within the area limits of this report.

* * *

OTHER LARGE FLOODS on the Clark Fork at Missoula occurred in May 1948, June 1953, and May 1947. The 1948 flood was only slightly lower than the 1964 flood, while the June 1953 and May 1947 floods were about 1 and 2 feet below the 1964 flood, respectively.

* * *

INTERMEDIATE REGIONAL FLOOD on the Clark Fork is a flood that has an average frequency of occurrence in the order of once in 100 years. The flood is determined from an analysis of floods on this stream and other streams in the same general area. The analysis indicates that the Intermediate Regional Flood for Clark Fork is about 1 to 2 feet higher than the June 1964 flood within the limits of this study.

* * *

STANDARD PROJECT FLOOD determinations indicate that floods could occur on the Clark Fork in the vicinity of Missoula about 2 feet higher than the June 1908 flood and about 3 to 7 feet higher than the June 1964 flood. The Standard Project Flood would be about 2 to 5 feet higher than the Intermediate Regional Flood.

* * *

FLOOD DAMAGES that would result from recurrences of major known floods and the Intermediate Regional Flood would be substantial. Extensive damages would be caused by the Standard Project Flood because of the wider extent, greater depths, and higher velocities.

* * *

MAIN FLOOD SEASON for the Clark Fork is in the spring. Most of the floods have resulted from melting snow during this time, though some floods have been augmented by heavy rains.

* * *

VELOCITIES OF WATER during major floods range up to 11 feet per second (about 7.5 miles per hour) in the channel of the Clark Fork. Velocities on the flood plain vary widely, depending on location but generally are less than 3 feet per second. During a Standard Project Flood, velocities would be extremely dangerous to life and property. They would range up to 14 feet per second in the river channel. On the flood plain, the corresponding figures would be 3 feet per second. Velocities greater than 3 feet per second, combined with depths of 2 feet or greater, are generally considered hazardous.

* * *

DURATION OF FLOODS on the Clark Fork is relatively long. Stages rise from low winter levels to flood peaks in several weeks as the winter accumulation of snow melts. During the flood of June 1964, the Clark Fork had a maximum rate of rise of about 2 feet per day and remained out of banks 4 days. The 1948 flood rose at practically the same rate, but remained out of banks 20 days. During Standard Project Flood on Clark Fork, the stream would rise 4 feet per day and would remain out of banks approximately 50 days.

* * *

HAZARDOUS CONDITIONS would occur during large floods as a result of the rising streams, high velocities, and deep flows.

* * *

FLOOD DAMAGE PREVENTION MEASURES. There are six existing, and one flood protective works being studied within the limits of the study area. There are no flood plain regulations in Missoula. Floodwalls and levees protect portions of the commercial and residential districts of Missoula.

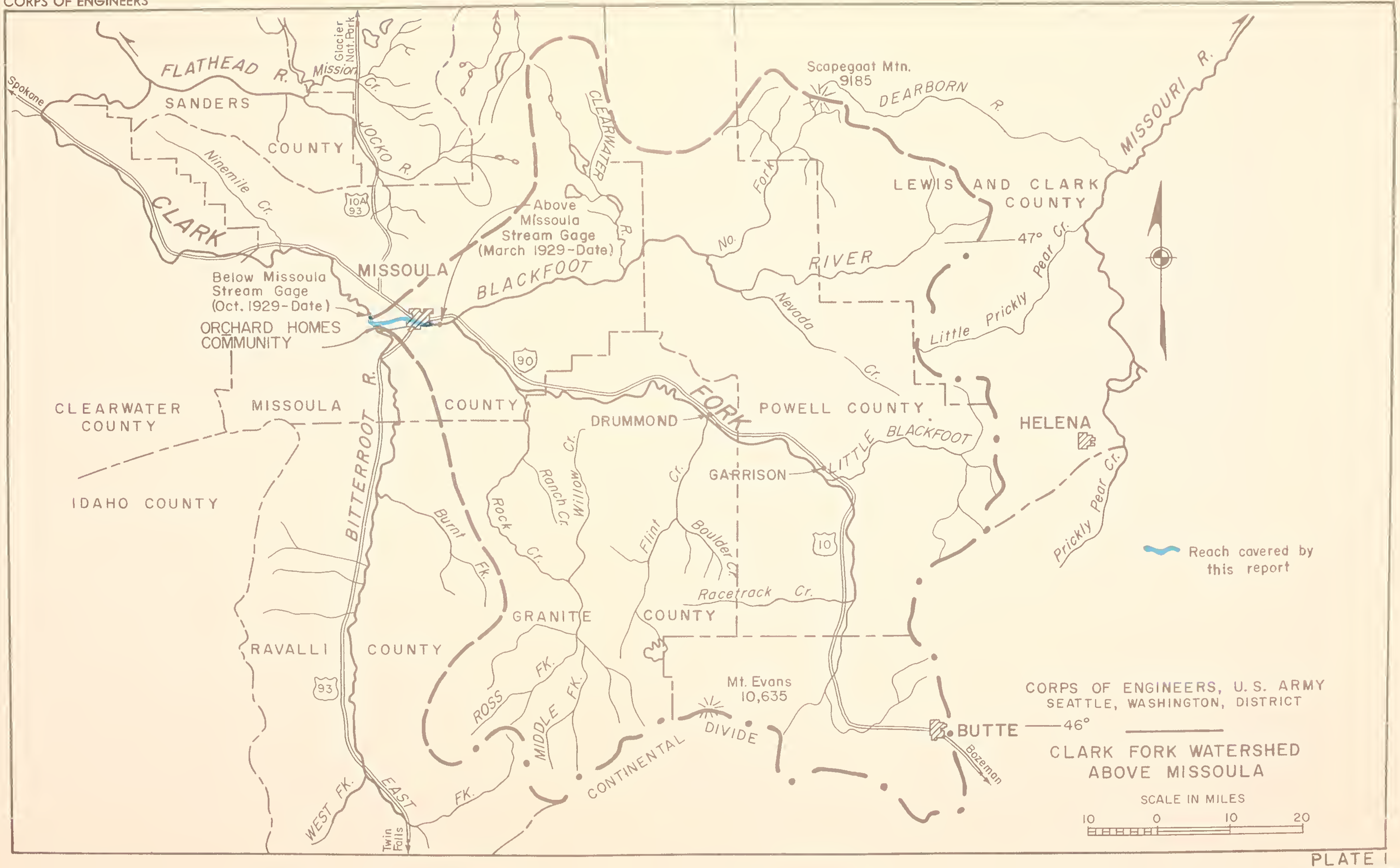
* * *

FUTURE FLOOD HEIGHTS that would be reached if the Intermediate Regional and Standard Project Floods occurred in the vicinity of Missoula are shown in Table 1. The table gives the comparison of these flood crests and also shows the comparison with the June 1964 flood for Clark Fork.

TABLE 1

RELATIVE FLOOD HEIGHTS

Flood	Location	Mile above Mouth	Estimated Peak Discharge	Above 1964 Flood
	Clark Fork			
June 10, 1964	N.P. Railway Bridge	357.0	31,700	0
Intermediate Regional			42,500	1.8
Standard Project			75,000	5.0



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CLARK FORK WATERSHED ABOVE MISSOULA

PLATE 1

GENERAL CONDITIONS
AND
PAST FLOODS

This section of the report is a history of floods on the Clark Fork in the vicinity of Missoula, in Missoula County, Montana. Missoula is on both banks of the Clark Fork about 7 miles above the mouth of the Bitterroot River. The portion of Clark Fork studied extends from the mouth of the Bitterroot River to river mile 360.0 above the city of Missoula, a distance of about 10 miles. The drainage basin of Clark Fork upstream of this study is 5,999 square miles, and lies wholly within Montana west of the Continental Divide.

The Clark Fork flows westerly from its source near Butte, Montana, through Missoula and on to Pend Oreille Lake in northern Idaho. The Clark Fork emerges from a narrow canyon immediately east of Missoula and continues on a westerly course through the city. The river channel downstream of Missoula follows a meandering course for several miles, is braided and shifts with each high water.

Most of the residential properties and the larger part of the business section of Missoula are on high ground above flood danger, but there are important commercial and residential developments on the flood plain. Orchard Homes, a suburban community downstream of Missoula, on the left bank of the Clark Fork is partially in the flood plain. Residential developments along the river have been flooded in the past. Damages from flooding are increasing with the passage of time because of the urban growth in the community.

The first records of river stage and discharge on the Clark Fork above Missoula date from March 1929, when the U. S. Geological Survey installed a recorder gage in a wooden shelter on the right bank 3 miles east of Missoula.

A search of the flood history developed information on the Clark Fork through Missoula and downstream to the mouth of the Bitterroot. Investigations were made following the floods of May 1948 and June 10, 1964. Local residents were interviewed. Field investigations and office computations were made to supplement the early data and to develop the flood profile for the largest recent known flood on Clark Fork, that of June 10, 1964. From historical documents and gage records, it has been possible to develop a history of known floods on Clark Fork covering the past 60 years.

CLARK FORK

Settlement

Subsequent to the recognition of Missoula County by the territorial legislature in 1865, Missoula was established as the county seat in 1866.

In 1864-65 Frank J. Worden and Company built a sawmill, a grist mill, and a business house at the present site of Missoula. They moved their store from Hell Gate, about 4 miles west, to the new building and called the new community Missoula Mills. Eventually the latter word was dropped and the town was named Missoula.

Timber is the most important natural resource in Missoula County and is the foundation on which the city of Missoula's economy has been built. Missoula County's 1.9 million acres includes 1.2 million acres of commercial forest land.

Agricultural resources are also important to the economy of Missoula. Livestock is the principal agricultural product with marketing receipts in 1963 for Missoula County amounting to $3.2 million. Crops in the county are hay, winter wheat, potatoes and barley.

Another of the resources in the Missoula area and one which will play an even more important economic role in the future is its scenic environment and outdoor recreation potential. Missoula lies between two of the nations most visited national parks, Yellowstone and Glacier, and has long served as an overnight stop for tourists visiting the two parks.

Missoula is recognized as the educational center of Montana, since it is the site of the University of Montana. The 1960 census gives the population of Missoula as 27,090 persons, and for Missoula County 44,663 persons.

Flood Damage Prevention Measures

A combination of levees and floodwalls, about 1.4 miles long, have been constructed on the right and left banks of the Clark Fork within the city limits of Missoula. These flood control projects afford protection to residential and commercial districts on the right bank; and the Intermountain Lumber Company and municipal swimming pool on the left bank, against flood flows having a frequency in excess of once in 200 years. The upstream portion of Orchard Homes is protected by about 4,700 feet of levee. The downstream end of the levee is not tied into high ground. Therefore, the residences at the downstream end of the levee are inundated by backwater effects as shown on Plate 6.

Flood Warning and Forecasting Services

The U. S. Weather Bureau at Missoula disseminates specific flood warnings and forecasts prepared by the Portland, Oregon River Forecasting Center of the U. S. Weather Bureau.

The Stream and Its Valley

The Clark Fork has a drainage area of 22,067 square miles above Pend Oreille Lake. The Clark Fork from its source south of Butte, Montana, flows northwesterly to Pend Oreille Lake in northeastern Idaho. The outlet of the lake becomes Pend Oreille River, which is a principal tributary of the Columbia River. The drainage basin of the Clark Fork upstream from the city of Missoula has an area of 5,999 square miles and lies wholly within Montana west of the Continental Divide. Plate 1 shows the watershed and stream drainage system for the Clark Fork above Missoula, Montana.

Elevations within the basin range from 3,000 feet at Missoula to over 10,000 feet at the Continental Divide. Major tributaries above Missoula include: The Blackfoot River which flows in a westerly direction and joins the Clark Fork about 6 miles upstream from the city of Missoula; the Little Blackfoot River which originates in the eastern portion of the drainage basin and flows westward to join the Clark Fork near the community of Garrison; Flint Creek which flows north to a confluence with the Clark Fork near the town of Drummond, and Rock Creek, a northward flowing stream, that enters the Clark Fork about 20 miles above Missoula.

The slope of the Clark Fork from its source to Missoula is steep, falling on the average about 62 feet per mile, but flattens to about 12 feet per mile in the study reach.

Within the study reach the flood plain varies from a few hundred feet at Missoula to about 2 miles wide downstream of Missoula. However, the area inundated by a severe flood such as the Standard Project Flood would spread out much farther, including reaches in the vicinity of Missoula.

Pertinent drainage areas of Clark Fork are given in Table 2.

TABLE 2

DRAINAGE AREAS IN WATERSHED OF CLARK FORK

Stream	Location	Mile above Mouth	Drainage Area sq. mi.
Clark Fork	Cabinet	149.5	22,067
	St. Regis	270.3	10,709
	Below Missoula	349.5	9,003
	Above Missoula	361.6	5,999
Flathead River			9,259
Bitterroot River			3,003
Blackfoot River			2,290

Developments in the Flood Plain

Plate 4 is an index map of the three sheets that show the flooded areas of Clark Fork. Plates 5, 6, and 7 show the flood plain of Clark Fork for the reach covered by this report. There are developments on both banks of the Clark Fork in the city of Missoula, but only scattered developments elsewhere. Most of the flood plain is devoted to agricultural or related purposes. Only a few structures in the flood plain of Clark Fork have been damaged by floods in the past; however, numerous ones were only slightly above past flood levels and the Intermediate Regional Flood.

The Standard Project Flood would flood homes along lower South Third Street, Rattlesnake Creek in north Missoula and the city park and swimming pool and Intermountain Lumber Company on the left bank. Extensive damages to agricultural land, buildings and secondary roads would result from such a flood in the area from Orchard Homes to the mouth of the Bitterroot River. A portion of the sewage treatment plant on the right bank at mile 355.0 would be inundated.

Bridges Across the Stream

Six highway and two railroad bridges cross the Clark Fork in the reach included in this study. Table 3 lists pertinent elevations and locations for these structures and shows their relation to the crest of the flood in June 1964 and the Intermediate Regional Flood. Figure 1 shows photographs of some of the bridges.

None of the bridges across Clark Fork are serious obstruction to stream overflow. All of the bridges are well above the crest of the June 1964 and the Intermediate Regional Flood. Calculations and observations indicate head losses (defined in the GLOSSARY of this report) at these structures would be negligible during high flood flows.

TABLE 3

BRIDGES ACROSS CLARK FORK

Mile above Mouth	Identification	Stream Bed Elev. feet	Intermediate Regional Flood Crest Elev. feet	June 1964 Flood Crest Elev. feet	Underclearance Elev. feet	Underclearance Above 1964 Flood feet
354.5	C.M. St. P. & P. Railroad	3130.0	3144.3	3143.4	3149.5	6.1
356.3	Russell Lincoln Street	3154.0	3166.2	3164.5	3170.6	6.1
356.5	California Street	3156.0	3168.4	3166.6	3172.4	5.8
357.0	N. P. Railroad	3160.0	3172.6	3170.8	3178.9	8.1
357.3	Parkway Street	3164.0	3175.7	3174.0	3181.4	7.4
357.6	Higgins Avenue	3168.0	3178.7	3177.1	3193.5	16.4
358.1	Madison Street	3164.0	3185.4	3183.7	3202.2	18.5
358.3	Van Buren Street	3168.0	3187.4	3185.4	3202.8	17.4

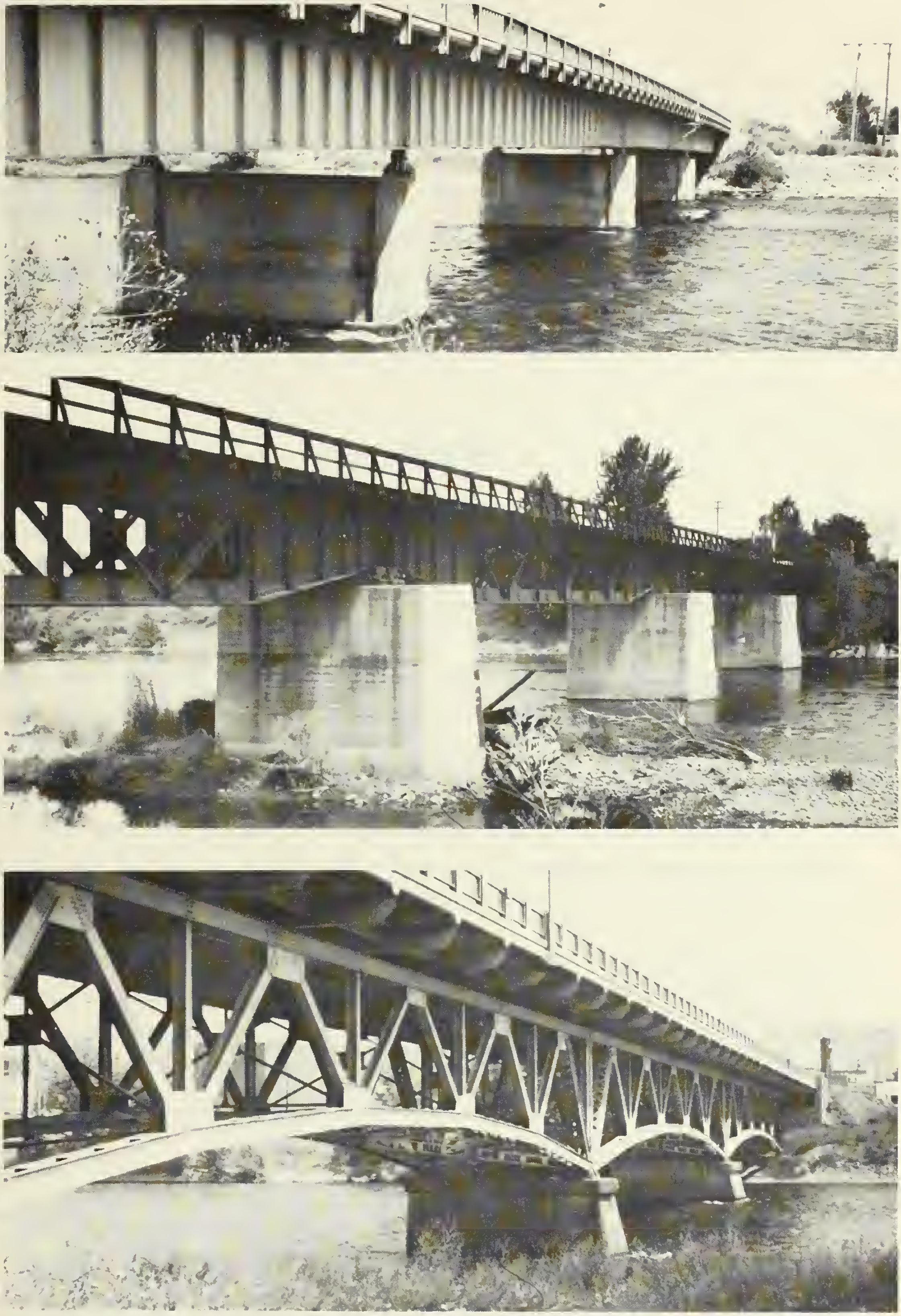


Figure 1.--CLARK FORK BRIDGES

Upper view is upstream side of Russell-Lincoln bridge at approximately Mile 356.3. Middle view is upstream side of N. P. Railroad bridge at approximately Mile 357.0. Lower view is upstream side of Parkway Bridge at approximatey Mile 357.3.

Obstructions to Flood Flow

There are three low-level diversion dams within the study reach. The dams were constructed to divert low flows of the Clark Fork to head gates on irrigation ditches. The effects of the dams are negligible during high flood flows.

FLOOD SITUATION

Flood Records

The recording of river stages and discharges on the Clark Fork in the vicinity of Missoula began with the establishment of a staff gage at downtown Missoula in 1899. This gage was discontinued in 1907. In May 1929, a recording gage was established at a site about 3 miles above Missoula, and continuous records at this site are available to date. As there is very little intervening flow between the 1899 and 1929 locations, peak flows recorded at each may be considered compatible. The 1908 flood peak was estimated by the U. S. Forest Service by comparing high water marks of this flood with subsequent floods.

To supplement the record obtained at the gaging station, above Missoula local residents were interviewed for information on dates and heights of floods. Newspaper files were searched, as were historical documents and records. These records and investigations have developed a knowledge of floods on Clark Fork covering the past 60 years.

Flood Stages and Discharges

Table 4 lists crest stages and discharges for the known floods exceeding bankfull stage of 10.0 feet at the gaging station on Clark Fork 3 miles east of Missoula, Montana. Table 5 lists the highest floods in order of magnitude. For floods since May 1929 the flood crest stages are those observed at the recorder gage.

Flood Occurrences

Plate 2 shows known crest stages and year of occurrence of known floods which have exceeded the bankfull stage of 10 feet at the gaging station, Clark Fork above Missoula.

Duration and Rate of Rise

Plate 3 shows the stage hydrographs at the stream gaging station, Clark Fork above Missoula for the floods of May 1948 and June 1964.

During the 1964 flood, the river rose at a maximum rate of about 2 feet per day and remained out of banks 4 days. The 1948 flood rose at practically the same rate, but remained out of banks 20 days. See pages 19 through 21 for details of these floods.

Velocities

During the May 1948 and 1964 floods velocities in the channel of Clark Fork near Missoula ranged up to 10 feet per second. Overbank velocities ranged up to 3 feet per second. During larger floods, velocities would be greater.

Flooded Areas, Flood Profiles, and Cross Sections

Plates 5, 6, and 7 show the areas along Clark Fork near Missoula that would be inundated by the Intermediate Regional Flood and also by the Standard Project Flood. The actual limits of these overflow areas on the ground may vary some from those shown on the aerial photo map because the scale of the map does not permit precise plotting of the flooded area boundaries.

TABLE 4

CLARK FORK NEAR MISSOULA, MONTANA

FLOOD CREST ELEVATIONS ABOVE BANKFULL STAGE

1899-1964

The table below lists all known floods above bankfull stage of 10 feet at the U. S. Geological Survey Gaging Station on right bank 3 miles downstream from Blackfoot River and 3 miles east of Missoula. Drainage area = 5,999 square miles. Zero of gage is 3,198.30 feet mean sea level, USC&GS 1929 GA, 1947 SA (Corps of Engineers Survey).

Date of Crest	Gage Heights Stage--Feet	Discharge - cfs
June 2, 1933	9.90	21,600
May 30, 1938	10.01	19,700
May 9, 1947	11.10	24,200
May 23, 1948	13.07	31,500
May 15, 1951	10.04	20,400
June 4, 1953	12.34	28,800
May 23, 1956	10.27	21,200
June 7, 1959	10.34	20,300
June 10, 1964	13.35	31,700
*June 20, 1899		36,400
*May 12, 1900		25,600
*May 18, 1901		20,200
*May 30, 1902		31,400
*June 4, 1903		25,000

*Known floods above bankfull stage taken at U. S. Geological Survey Gaging Station on right bank about 400 feet upstream from Northern Pacific Railroad Bridge at Missoula, discontinued 1907.

TABLE 5

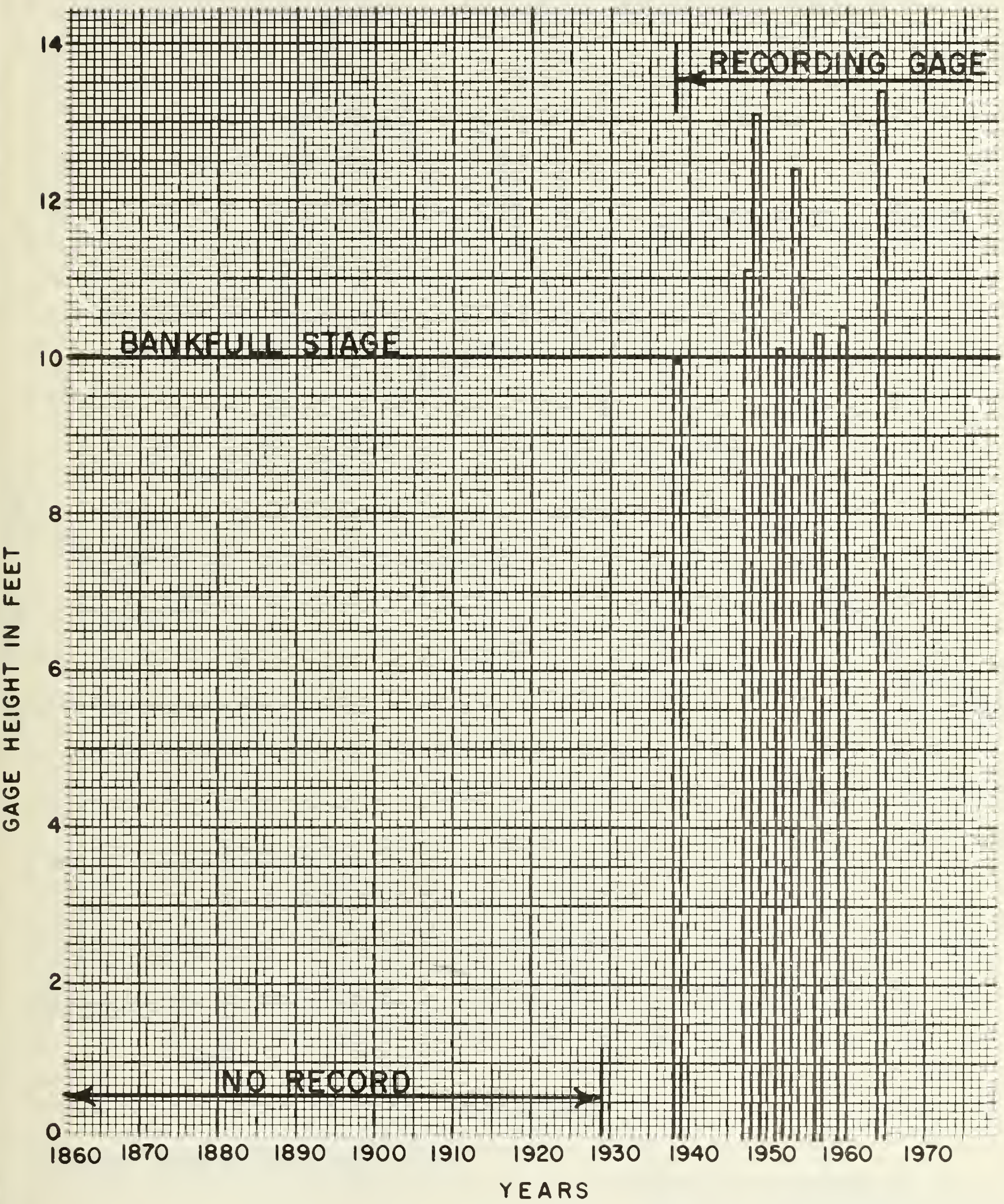
HIGHEST TEN KNOWN FLOODS IN ORDER OF MAGNITUDE

CLARK FORK IN THE VICINITY OF MISSOULA, MONTANA

Order No.	Date of Crest	Gage Height feet	Estimated Peak Discharge cfs
*+ 1	June 1908		51,000
+ 2	June 20, 1899		36,400
3	June 10, 1964	13.35	31,700
4	May 23, 1948	13.07	31,500
+ 5	May 30, 1902		31,400
6	June 4, 1953	12.34	28,800
+ 7	May 12, 1900		25,600
+ 8	June 4, 1903		25,000
9	May 9, 1947	11.10	24,200
10	June 2, 1933	9.90	21,600

*No record - estimated by U. S. F. S. 1936

+No record of gage height



Note: Stream gage at river mile 361.6
Zero of gage is elevation 3198.30

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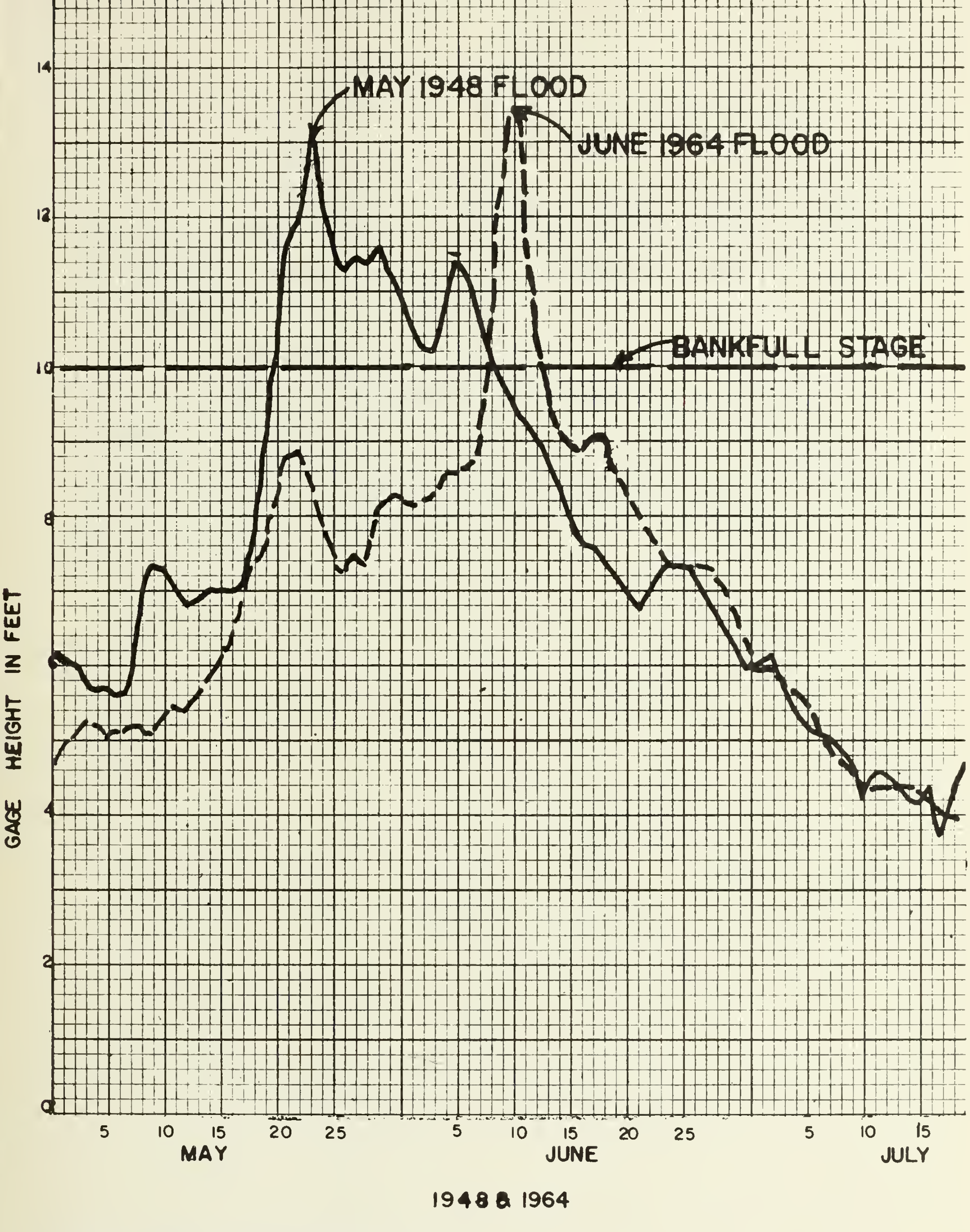
FLOODS ABOVE
BANKFULL STAGE
CLARK FORK
ABOVE
MISSOULA, MONTANA
NOVEMBER, 1967

PLATE 2



Stream Gage at River Mile. 361.6

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STAGE HYDROGRAPHS
CLARK FORK
ABOVE
MISSOULA, MONTANA
NOVEMBER, 1967

PLATE 3

Plate 8 shows the high water profile for the flood of June 1964. Also shown are the profiles for the Intermediate Regional Flood and the Standard Project Flood discussed on pages 22 and 23 of this report.

Plate 9 shows 5 cross sections that are typical of the total of 22 sections obtained for the Clark Fork in the reach investigated. The locations of all sections are shown on Plates 5, 6, and 7. The elevation and extent of overflow of the Intermediate Regional Flood and the Standard Project Flood are indicated on these sections.

FLOOD DESCRIPTIONS

Following are descriptions of known large floods that have occurred on Clark Fork near Missoula. These are based upon newspaper accounts, historical records, and field investigations.

1908 Flood

Little is known of the meteorological and hydrologic conditions that led to the flood of June 1908, as precipitation and streamflow data are almost nonexistant. However, we can conclude from the available records, that extremely heavy rainfall the first few days in June, was the primary cause of the flood. Winter precipitation data indicate that the 1907-1908 winter snowfall was below normal, possibly by as much as 40 percent. Heavy rains, beginning as early as May 25, together with snowmelt, probably raised the river to near channel capacity by the first of June. Rainfall increased in intensity on the 4th and 5th of June, and as a result, the river probably peaked sometime between the 5th and 7th of June. A precipitation gage at Anaconda, in the southeastern corner of the basin, recorded a total of 6.9 inches of rain from the 25th of May to the 6th of June. The 1908 U. S. Weather Bureau Climatological Report for Montana gives the following description of the floods that year in western Montana:

"The greatest property loss, due to flood, in the history of the State was caused by high water in the various streams from the 3rd to the 6th of June. Nearly all of the small streams in the southwestern portion of the State were at flood stage for several days, and many of them reached the highest stage ever known."

"The greatest damage was to railroad property. The main line of the Northern Pacific was damaged at various points from Livingston westward beyond Missoula, the most destructive floods being in the Hell Gate and Blackfoot Rivers from Missoula eastward.

Several miles of track and many bridges were washed out, and for a considerable distance the entire road bed was destroyed. On the line of the Great Northern from Butte to Great Falls, the damage was alsmost as great, and traffic on both of these lines, from Helena west and north, was entirely abandoned for more than two weeks. For twenty-four hours, on the 4th and 5th, Helena and Butte were without train service in any direction."

The following is an excerpt from the Missoulian-Sentinel concerning the 1908 flood at Missoula as recalled by that paper for the purpose of comparison with the large 1948 flood:

June 6, 1948

"Most conspicuous victim of the 1908 flood was the Higgins Bridge which on the night of June 5, 1908, lost its center span. A south span followed its neighbor in the river a few days later. The north and south sides of the city were isolated from each other, old-timers recall."

May 1948

The flood of May 1948 at Missoula was the result of a heavy snow runoff, augmented by rain. Cool, wet weather, prevailing until mid-May increased the water content in the above-normal winter snowpack and delayed its runoff. Temperatures began increasing on May 15, and reached the mid-70's at Missoula on the 16th and 17th. The resulting melting snow raised the river to within a foot of bankfull stage by the 19th. Rain began falling in the basin on the 19th and continued intermittently through the 23rd, totaling over an inch at Missoula. The melting snow, together with this rain, pushed the river stage to a peak of 13.07 on the 23rd of May. As shown on the stage hydrograph of the flood, plate 3, the river was above bankfull stage for 20 days. Figure 2 gives views of the 1948 flood conditions. The following is an excerpt from the Missoulian-Sentinel of May 25, 1950 recalling an incident concerning the 1948 flood at Orchard Homes:

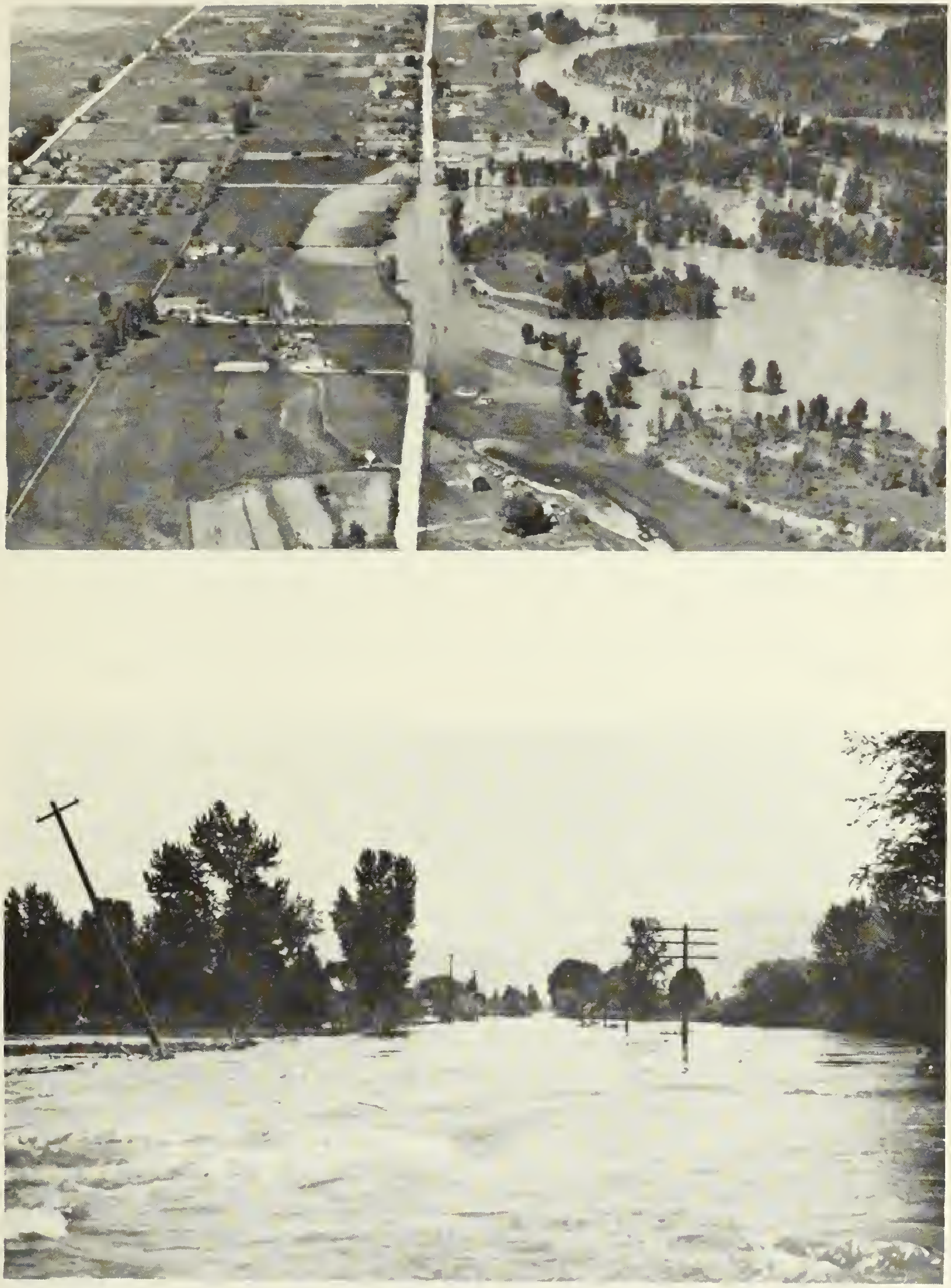


Figure 2.--FLOOD SCENES IN ORCHARD HOMES--MAY 23,1948

The upper aerial view is looking west at Orchard Homes community in vicinity of Howard and Tower Streets. Lower view is looking west along Third Street in Orchard Homes.

[illegible]

"On June 26, 1948, Mr. and Mrs. Rene A. Keck were drowned when the boat in which they and Mr. Minster were riding capsized in the flood channel. They were en route to reach the Keck home which has been marooned by flood waters for a month, and Mr. Minster narrowly escaped with his life. He was forced to leave his home for more than a month."

June 1964

Snow course measurements taken on March 1, 1964, indicated that the snowpack in the Clark Fork Basin was below normal. March and April precipitation, however, increased the water content of the snow to slightly above normal, and river stage forecasts made on the 1st of May predicted a flood stage at Missoula of slightly above bankfull stage. Melting snow had increased the river stage to within a foot of bankfull capacity by June 7, when unprecedented rains began to fall over the Continental Divide northeast of Missoula. The Clark Fork Basin escaped the heaviest precipitation, which amounted to 14 inches in 30 hours in places; but the rain that did fall in the basin was heavy enough to increase the river stage to a peak of 13.35 on June 9th. Because the highest stages of the flood were primarily the result of heavy rain, the duration of the flood above channel capacity, 4 days, was shorter in comparison to the 1948 flood. A stage hydrograph of the 1964 flood is shown on Plate 3. The following is an excerpt from the Missoulian-Sentinel concerning the 1964 flood at Orchard Homes:

June 10, 1964

"A small spur levy built in 1948 near the end of Stone Street was re-enforced with sandbags by volunteers and National Guardsmen. Residents of trailers and houses at the north end of Tower Street evacuated the area."

FUTURE FLOODS

This section of the report discusses the Standard Project Flood and the Intermediate Regional Flood on Clark Fork, in the vicinity of Missoula, Montana, and some of the hazards of great floods. Floods of the size of the Standard Project Flood represent reasonable upper limits of expected flooding. Those of the size of the Intermediate Regional Flood represent floods that may reasonably be expected to occur more frequently, although they will not be as high as the infrequent Standard Project Flood.

Large floods have been experienced in the past on streams in the general geographical and physiographical region of Missoula. Heavy storms similar to those causing these floods could occur over the watershed of Clark Fork which would result in floods on this stream comparable in size with those experienced on neighboring streams. In determining future floods on the Clark Fork, we must consider storms and floods that have occurred in the region on watersheds whose topography, watershed cover, and physical characteristics are similar to those of this stream.

DETERMINATION OF INTERMEDIATE REGIONAL FLOODS

The Intermediate Regional Flood is defined as a flood at any given location having an average frequency of occurrence in the order of once in 100 years, although the flood may occur in any year. Some probability estimates are based on statistical analyses of streamflow records available for the watershed under study, but limitations in such records usually require analyses of rainfall and runoff characteristics in the "general region" of the area under study. The Intermediate Regional Flood represents a major flood, although it is much less severe than the Standard Project Flood.

The Intermediate Regional Flood for the Clark Fork in the vicinity of Missoula was based on the 46 years of streamflow records at or near Missoula, published by the U. S. Geological Survey. Table 6 lists the maximum known floods that have occurred on watersheds comparable with Clark Fork within the same geographical region. The results of the statistical analysis of these data indicate that the Intermediate Regional Flood for the stream gage, Clark Fork above Missoula would have a peak discharge of 42,500 cubic feet per second.

Intermediate Regional Floods may occur on Clark Fork in the reach investigated that would be from 1 to 2 feet higher than the June 1964 flood.

DETERMINATION OF STANDARD PROJECT FLOODS

Only in rare instances has a specific stream experienced the largest flood that is likely to occur. Severe as the maximum known flood may have been on any given stream, it is a commonly accepted fact that, in practically all cases, sooner or later a larger flood can and probably will occur. A Standard Project Flood is defined as the largest flood that can be experienced from the most severe combination of meteorological and hydrological conditions that is considered reasonably characteristic of the geographical region involved.

The Standard Project Flood at Missoula is estimated to be 75,000 cubic feet per second.

Frequency

No frequency is assigned to the Standard Project Flood. The occurrence of such a flood would be a rare event; however, it could occur in any year.

TABLE 6

MAXIMUM KNOWN FLOOD DISCHARGES ON STREAMS IN THE REGION OF MISSOULA, MONTANA

Stream	Location	Drainage Area sq. mi.	Date	Peak Discharge Amount cfs	Peak Discharge Per Sq. Mi. cfs
Flathead River	Near Polson	7,096	May 29, 1928	82,800	12
Flathead River	At Columbia Falls	4,464	June 9, 1964	176,000	39
Bitterroot River	Near Florence	2,354	June 9, 1964	20,300	9
Blackfoot River	Near Bonner	2,290	June 10, 1964	19,200	8
Flathead River	Near Columbia Falls	1,553	June 9, 1964	69,100	44
Flathead River	Near West Glacier	1,128	June 9, 1964	140,000	124
Bitterroot River	Near Darby	1,049	May 9, 1947	11,500	11
Flathead River	At Essex (Middle Fork)	510	June 8, 1964	75,300	148
Bitterroot River	Near Conner (East Fork)	381	June 8, 1964	3,270	9
Bitterroot River	Near Conner (West Fork)	317	May 8, 1947	4,060	13
Blackfoot River	Near Ovando	1,274	June 4, 1953	14,600	11

Possible Larger Floods

Floods larger than the Standard Project Flood are possible; however, the combination of factors that would be necessary to produce such floods would seldom occur. The consideration of floods of this magnitude is of greater importance in some problems than in others but should not be overlooked in the study of any problem.

HAZARDS OF GREAT FLOODS

The amount and extent of damage caused by any flood depend in general upon how much area is flooded, the height of flooding, the velocities of flow, the rate of rise, and the duration of flooding.

Areas Flooded and Heights of Flooding

The areas along Clark Fork subject to flooding by the Standard Project Flood and the Intermediate Regional Flood are shown on Plates 5 through 7. Depths of flow can be estimated from the crest profile which is shown on Plate 8.

The profile for the stream was computed by using stream characteristics for selected reaches as determined from observed flood profiles, topographic maps, and valley cross sections which were surveyed in September 1966. The elevations shown on Plate 8 and the overflow areas shown on Plates 5 through 7 have been determined with an accuracy consistent with the purposes of this study and the accuracy of the basic data.

The profiles of the Standard Project Flood and the Intermediate Regional Flood depend in part upon the degree of destruction or clogging of various bridges during the flood. Because we cannot forecast these events, we assumed all bridge structures would stand, and no clogging would occur.

The Standard Project Flood profile for Clark Fork is 3 to 7 feet higher than the June 1964 flood. The maximum difference occurs at the upstream limit of the study area and is the result of narrowing of the valley.

The Intermediate Regional Flood profile for Clark Fork is 1 to 2 feet higher than the June 1964 flood.

Figures 3 and 4 on page 27 show the heights that would be reached by the Standard Project Flood and the Intermediate Regional Flood on facilities presently existing within the flood plain in the vicinity of Missoula.

Velocities, Rates of Rise, and Duration

Water velocities during floods depend largely upon the size and shape of the cross section, the condition of the stream, and the bed slope, all of which vary on different streams and at different locations on the same streams.

The maximum velocities that would occur in the main channel and overbank areas of Clark Fork are 11 and 3 feet respectively, during the Intermediate Regional Floods.

The maximum velocities that would occur in the main channel and overbank areas of Clark Fork are 14 and 3 feet respectively, during the Standard Project Floods.

Table 7 lists the total rise above low water to the crest of the Intermediate Regional Flood, and the duration above bankfull stage of the Intermediate Regional Flood for Clark Fork.

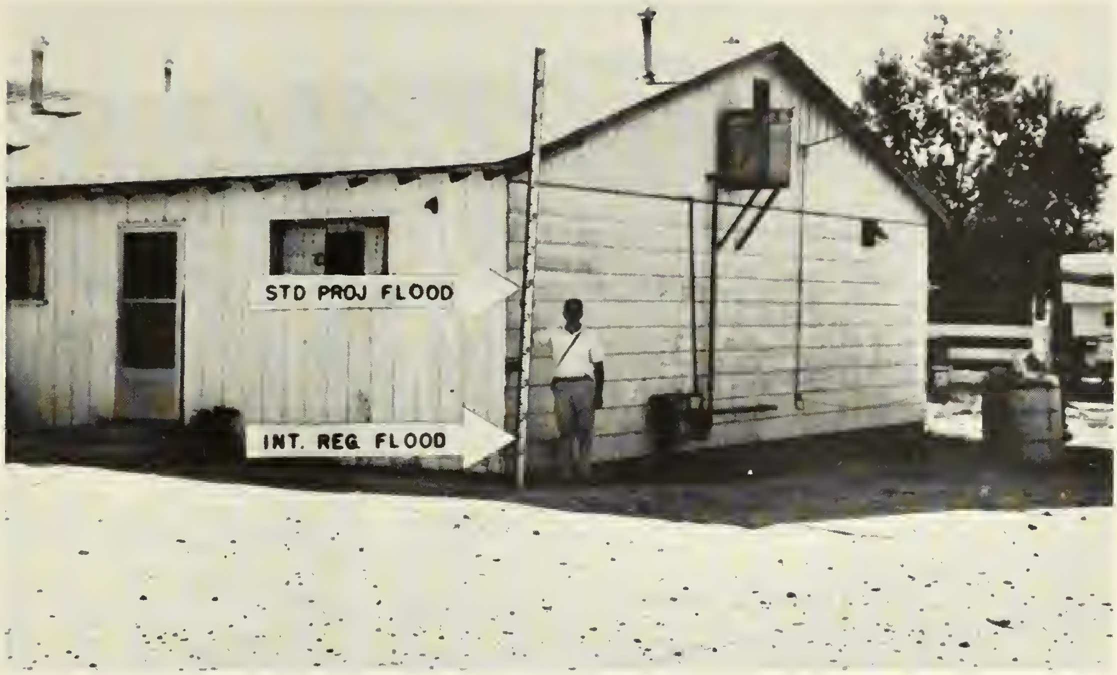


Figure 3.--FLOOD HEIGHTS AT AMVETS CAFE AND TAVERN

Amvets is located at the corner of Arlington Street and River Avenue. The levels reached by the Intermediate Regional Flood and Standard Project Flood are shown.

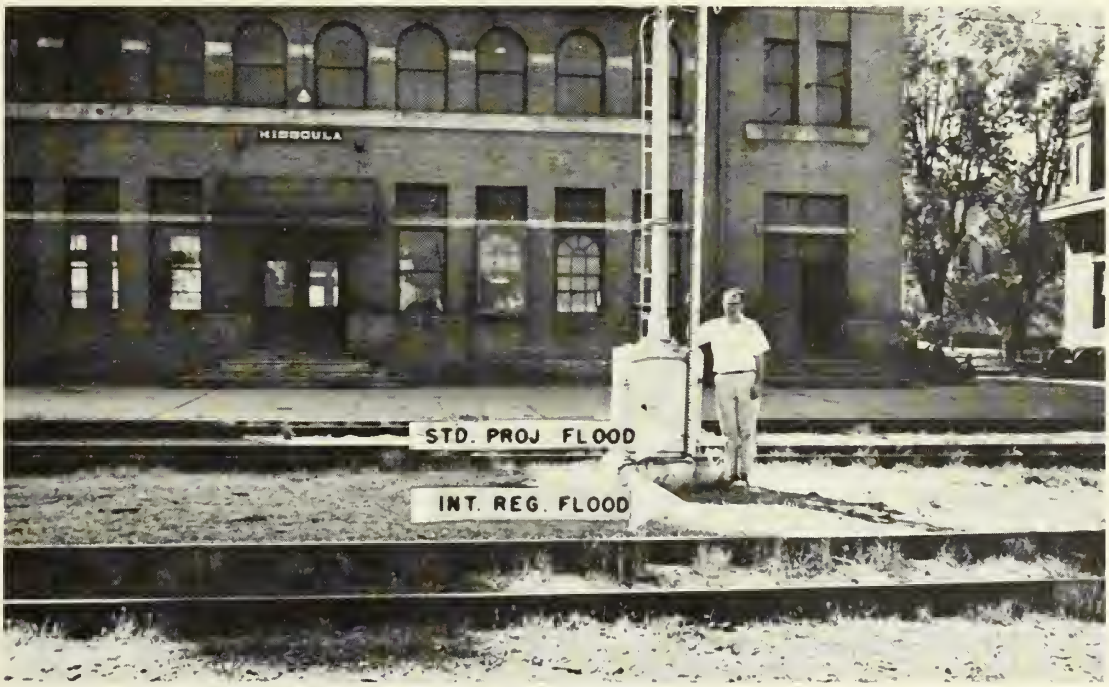


Figure 4.--FLOOD HEIGHTS AT C. M. ST. P. & P. R.R. DEPOT

The depot is on the left bank 200 feet downstream of the Higgins Avenue Bridge. Arrows show heights of the Standard Project Flood and the Intermediate Regional Flood.

TABLE 7

INTERMEDIATE REGIONAL FLOOD

RATES OF RISE AND DURATION

Stream	Location	Height of Rise feet	Maximum Rate of Rise ft. per day	Duration above Bankfull days
Clark Fork	Madison St. Bridge	14.0	3	30

Table 8 lists the total rise above low water to the crest of the Standard Project Flood and the duration above bankfull stage of the Standard Project Flood for Clark Fork.

TABLE 8

STANDARD PROJECT FLOOD

RATES OF RISE AND DURATION

Stream	Location	Height of Rise feet	Maximum Rate of Rise ft. per day	Duration above Bankfull days
Clark Fork	Madison St. Bridge	18.0	4	50

These long-duration floods and high stream velocities would create a hazardous situation in developed areas. Velocities greater than 3 feet per second combined with depths of 2 feet or greater are generally considered hazardous.

GLOSSARY OF TERMS

Flood: An overflow of lands not normally covered by water and that are used or usable by man. Floods have two essential characteristics: The inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river or stream or an ocean, lake, or other body of standing water.

Normally a "flood" is considered as any temporary rise in stream flow or stage, but not the ponding of surface water, that results in significant adverse effects in the vicinity. Adverse effects may include damages from overflow of land areas, temporary backwater effects in sewers and local drainage channels, creation of unsanitary conditions or other unfavorable situation by deposition of materials in stream channels during flood recessions, rise of ground water coincident with increased stream flow, and other problems.

Flood Crest: The maximum stage or elevation reached by the waters of a flood at a given location.

Flood Peak: The maximum instantaneous discharge of a flood at a given location. It usually occurs at or near the time of the flood crest.

Flood Plain: The relatively flat area or low lands adjoining the channel of a river, stream or watercourse or ocean, lake, or other body of standing water, which has been or may be covered by flood water.

Flood Profile: A graph showing the relationship of water surface elevation to location, the latter generally expressed as distance above mouth for a stream of water flowing in an open channel. It is generally drawn to show surface elevation for the crest of a specific flood, but may be prepared for conditions at a given time or stage.

Flood Stage: The stage or elevation at which overflow of the natural banks of a stream or body of water begins in the reach or area in which the elevation is measured.

Head Loss: The effect of obstructions, such as narrow bridge openings or buildings that limit the area through which water must flow, raising the surface of the water upstream from the obstruction.

Intermediate Regional Flood: A flood having an average frequency of occurrence in the order of once in 100 years although the flood may occur in any year. It is based on statistical analyses of streamflow records available for the watershed and analyses of rainfall and runoff characteristics in the "general region of the watershed."

Left Bank: The bank on the left side of a river, stream, or watercourse, looking downstream.

Low Steel (or Underclearance): See "Underclearance."

Right Bank: The bank on the right side of a river, stream, or watercourse, looking downstream.

Standard Project Flood: The flood that may be expected from the most severe combination of meteorological and hydrological conditions that is considered reasonably characteristic of the geographical area in which the drainage basin is located, excluding extremely rare combinations. Peak discharges for these floods are generally about 40 percent to 60 percent of the Probable Maximum Floods for the same basins. Such floods, as used by the Corps of Engineers, are intended as practicable expressions of the degree of protection that should be sought in the design of flood control works, the failure of which might be disastrous.

Underclearance: The lowest point of a bridge or other structure over or across a river, stream, or watercourse that limits the opening through which water flows. This is referred to as "low steel" in some regions.

AUTHORITY, ACKNOWLEDGMENTS, AND INTERPRETATION OF DATA

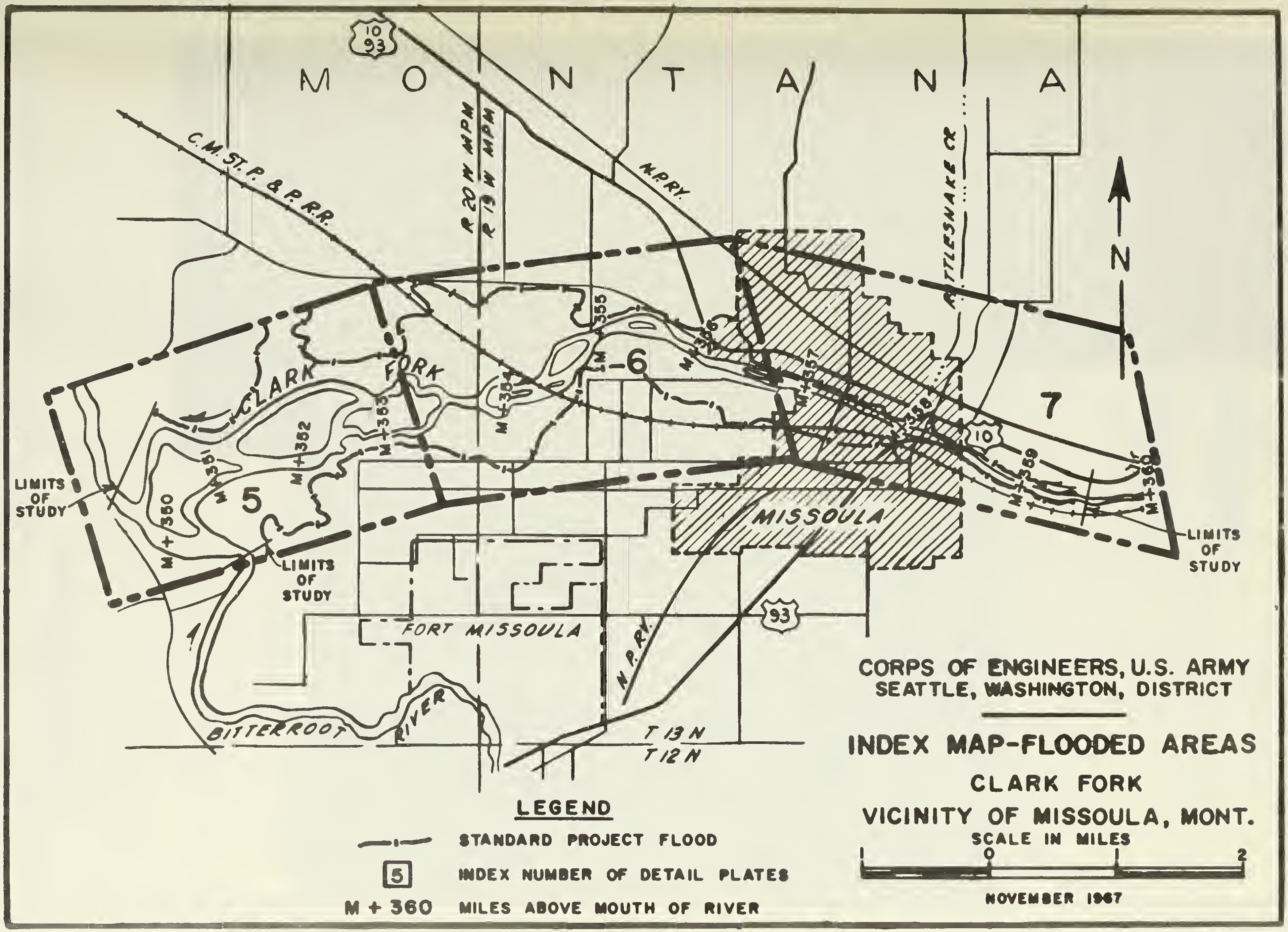
This report has been prepared in accordance with the authority granted by Section 206 of the Flood Control Act of 1960 (PL 86-645), as amended.

* * *

Assistance and cooperation of the U. S. Weather Bureau, U. S. Geological Survey, Montana State Water Resources Board, the city of Missoula, and private citizens in supplying useful data are appreciated.

* * *

This report presents the local flood situation for Missoula. The Seattle District of the Corps of Engineers will, upon request, provide technical assistance to Federal, State, and local agencies in the interpretation and use of the information contained herein and will provide other available flood data related thereto.



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SEATTLE, WASHINGTON, DISTRICT

INDEX MAP-FLOODED AREAS

CLARK FORK
VICINITY OF MISSOULA, MONT.

NOVEMBER 1967

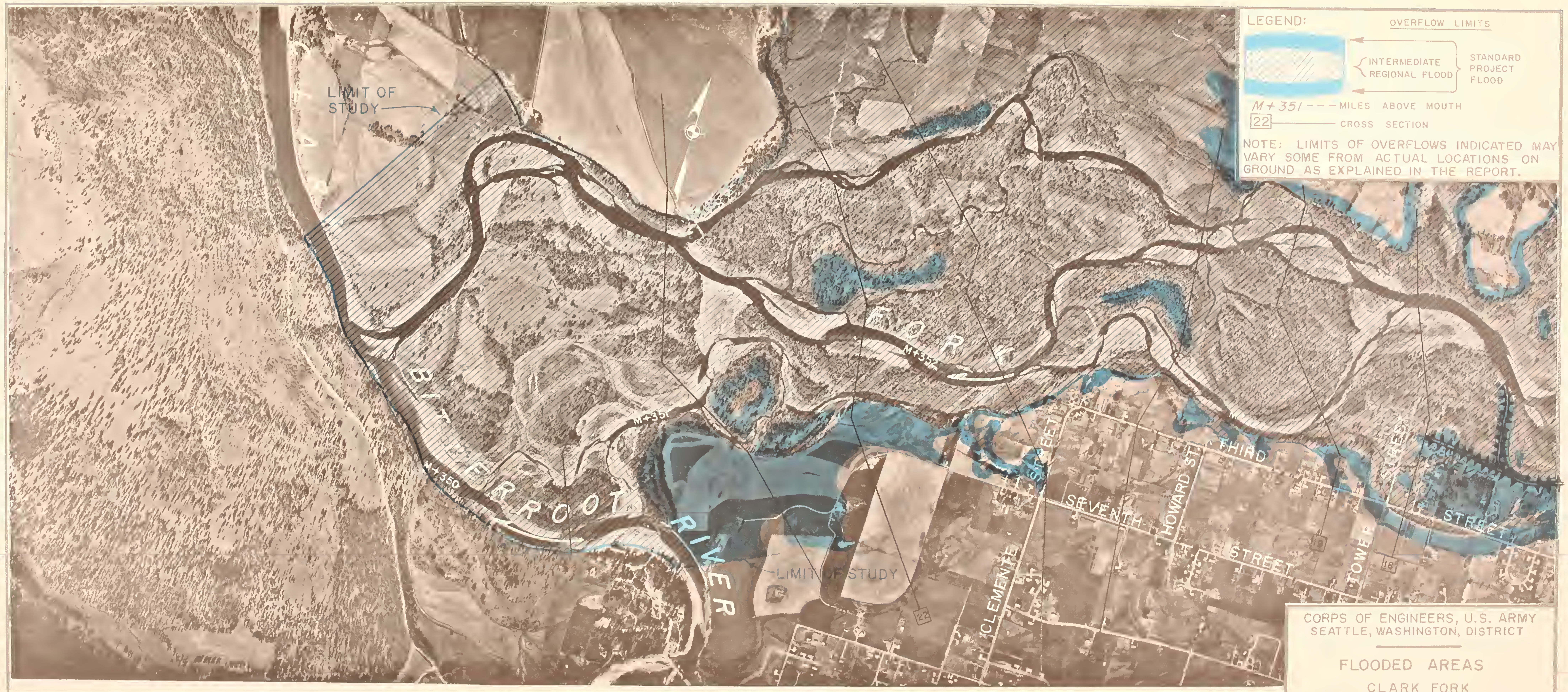
LEGEND

STANDARD PROJECT FLOOD

5 INDEX NUMBER OF DETAIL PLATES

M + 360 MILES ABOVE MOUTH OF RIVER

PLATE 4



NOTE: LIMITS OF OVERFLOWS INDICATED MAY VARY SOME FROM ACTUAL LOCATIONS ON GROUND AS EXPLAINED IN THE REPORT.

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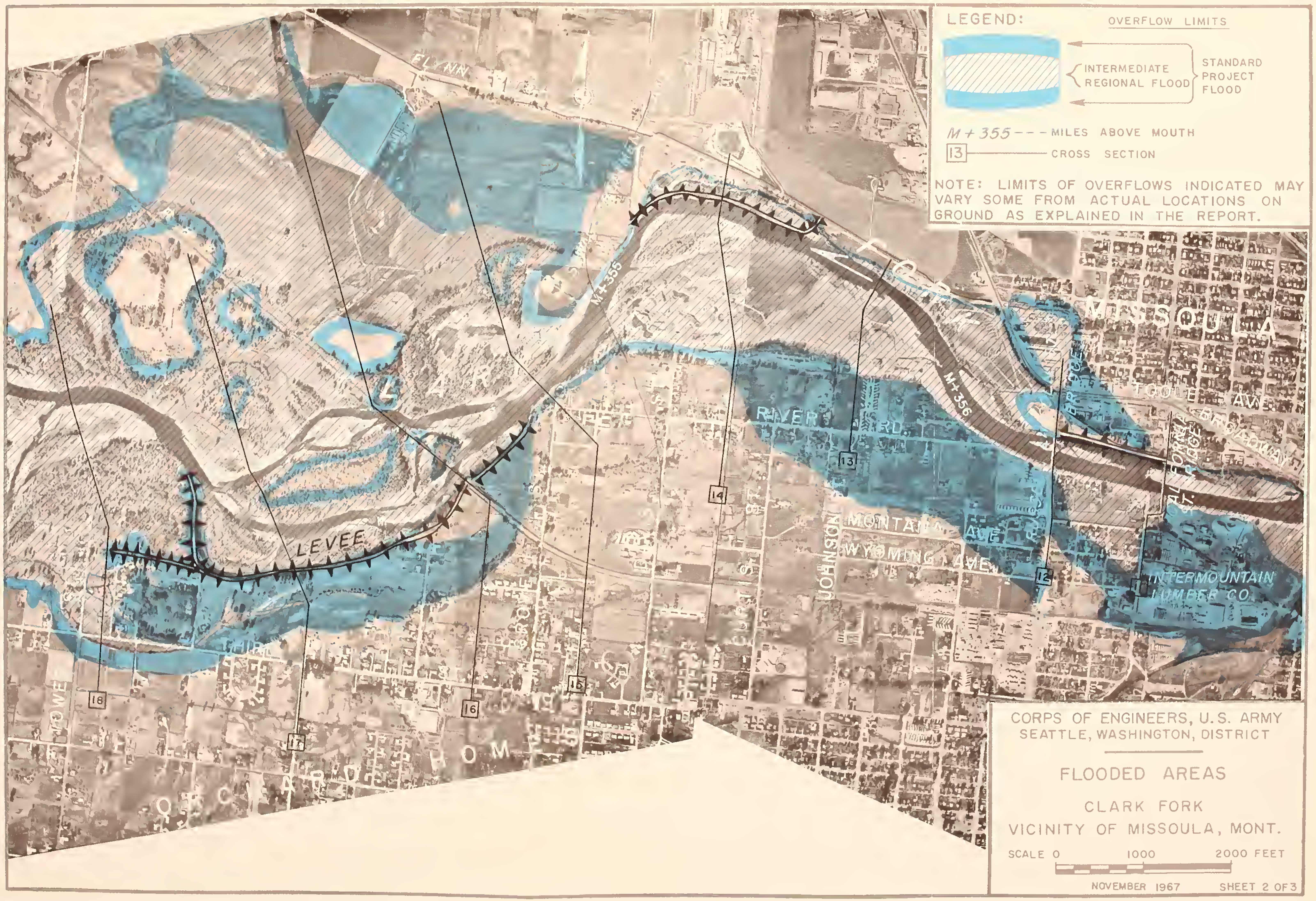
FLOODED AREAS
CLARK FORK
VICINITY OF MISSOULA, MONT.

SCALE 0 1000 2000 FEET

NOVEMBER 1967 SHEET 1 OF 3

PLATE 5



NOTE: LIMITS OF OVERFLOWS INDICATED MAY VARY SOME FROM ACTUAL LOCATIONS ON GROUND AS EXPLAINED IN THE REPORT.

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FLOODED AREAS

CLARK FORK
VICINITY OF MISSOULA, MONT.

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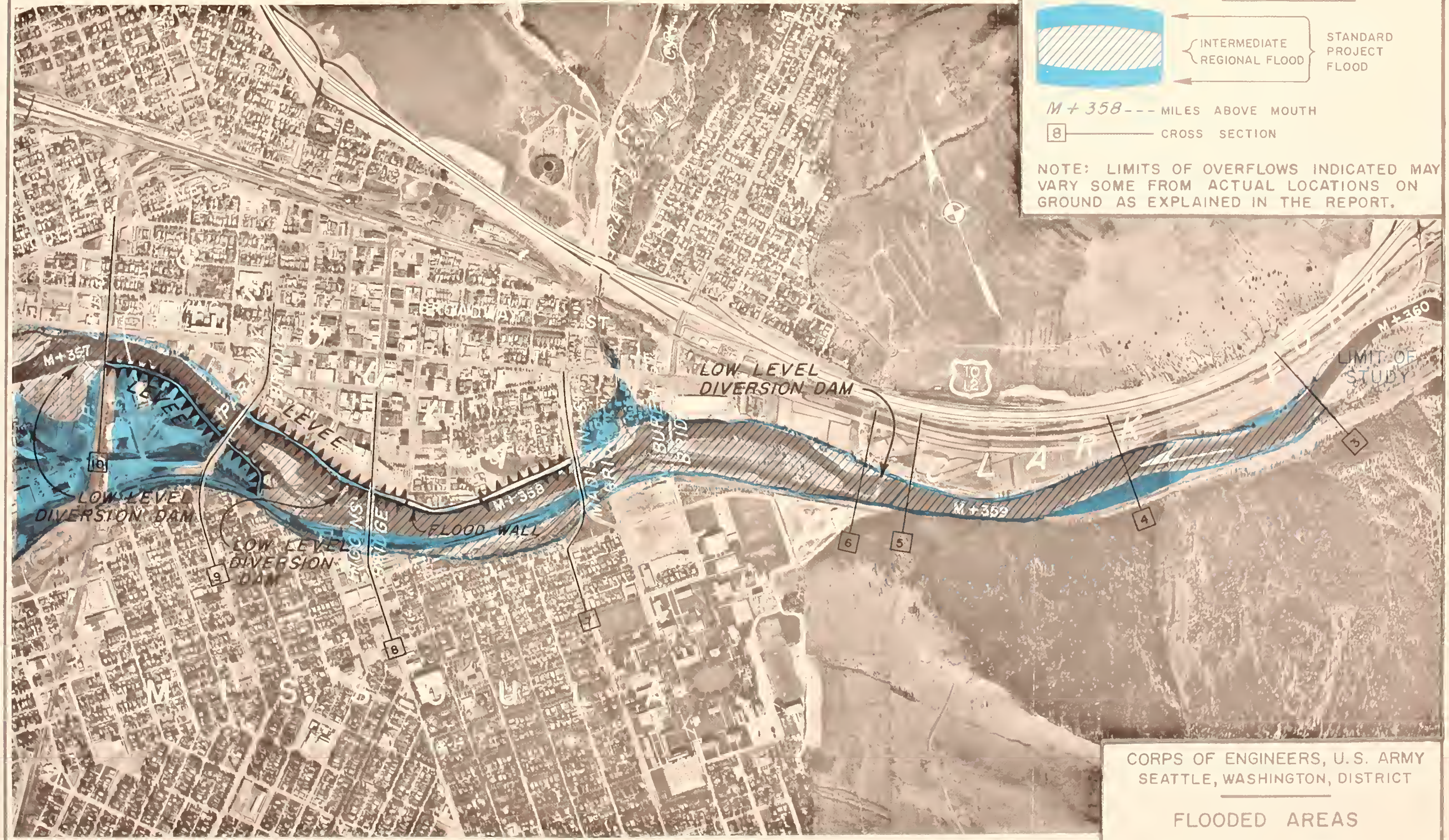
PLATE 6



LEGEND:

OVERFLOW LIMITS

▨	INTERMEDIATE REGIONAL FLOOD	STANDARD PROJECT FLOOD

M+358 --- MILES ABOVE MOUTH

8 ——— CROSS SECTION

NOTE: LIMITS OF OVERFLOWS INDICATED MAY VARY SOME FROM ACTUAL LOCATIONS ON GROUND AS EXPLAINED IN THE REPORT.

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FLOODED AREAS
CLARK FORK
VICINITY OF MISSOULA, MONT.

SCALE 0 1000 2000 FEET

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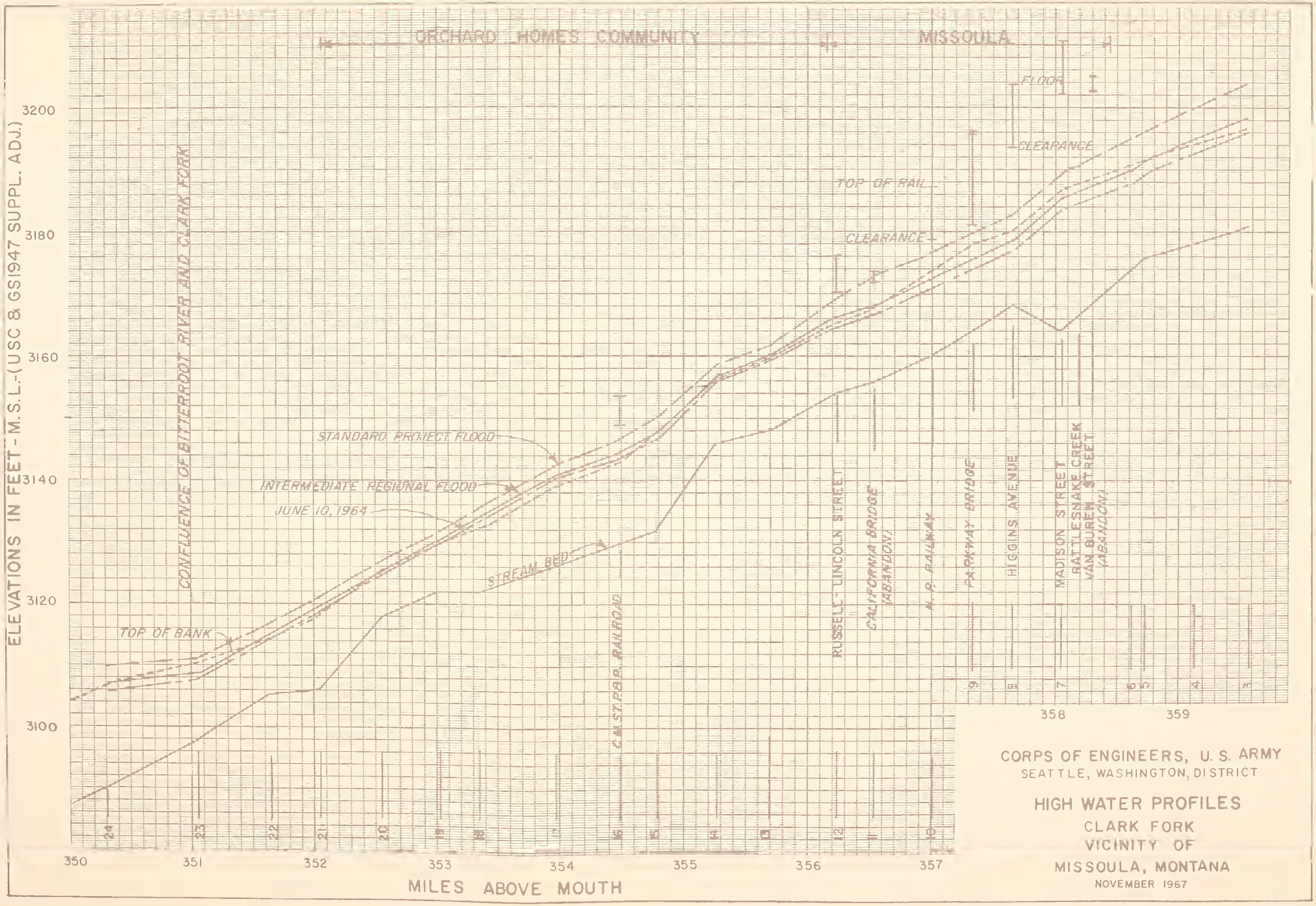
PLATE 7



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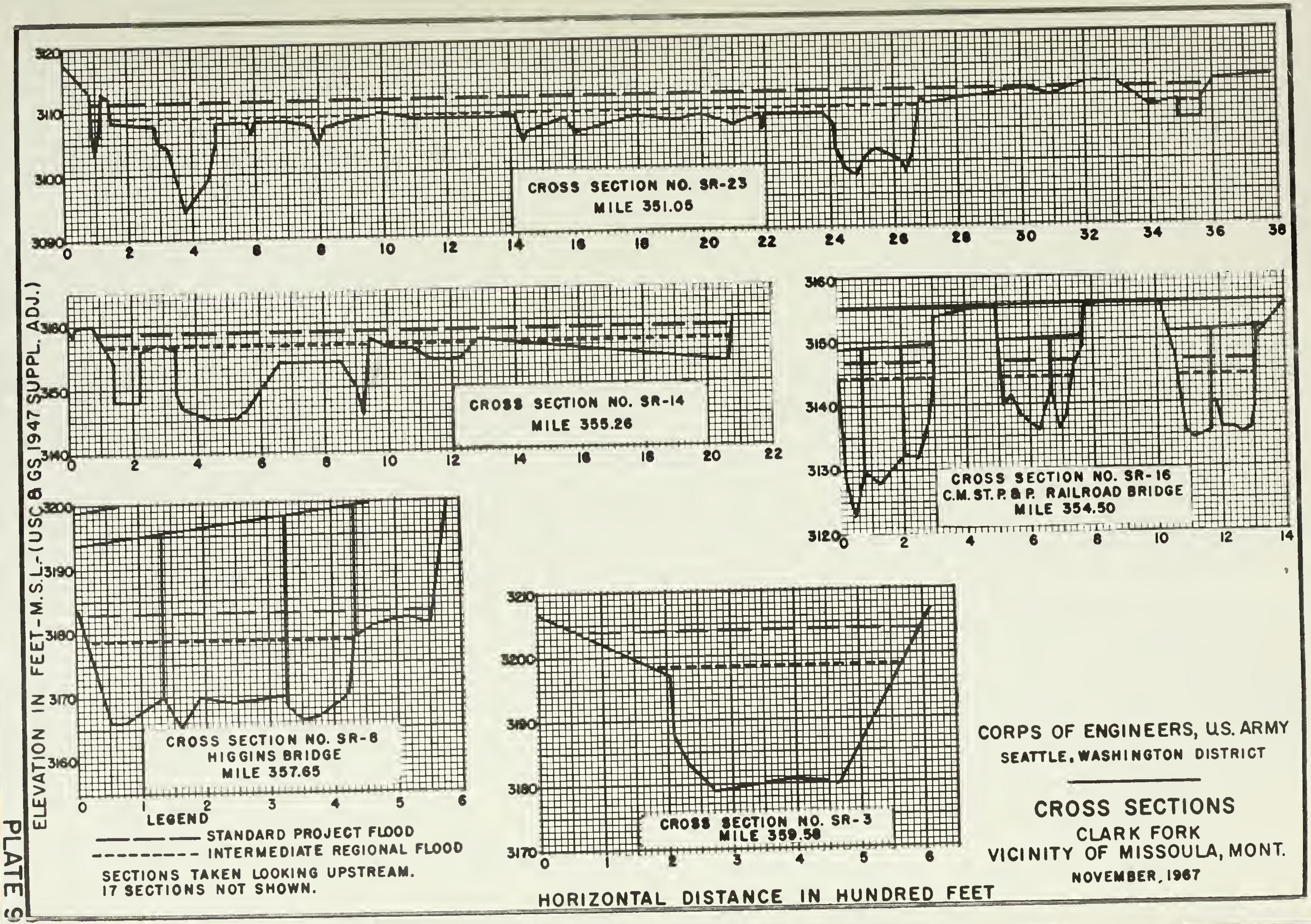
HIGH WATER PROFILES
CLARK FORK
VICINITY OF
MISSOULA, MONTANA
NOVEMBER 1967

PLATE 8



SECTIONS TAKEN LOOKING UPSTREAM.
17 SECTIONS NOT SHOWN.

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CROSS SECTIONS
CLARK FORK
VICINITY OF MISSOULA, MONT.
NOVEMBER, 1967

PLATE 9